

REPORT DOCUMENTATION PAGE					<i>Form Approved</i> OMB No. 0704-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.						
1. REPORT DATE (DD-MM-YYYY) 14-08-2015		2. REPORT TYPE Final			3. DATES COVERED (From - To) 15 May 2014 – 14 Aug 2015	
4. TITLE AND SUBTITLE Investigating perturbation electric fields and their effects on the coupled low-, mid- and high-latitude ionosphere				5a. CONTRACT NUMBER FA2386-14-1-4077		
				5b. GRANT NUMBER Grant 13IOA006_144077		
				5c. PROGRAM ELEMENT NUMBER 61102F		
6. AUTHOR(S) Dr. Ildiko Horvath				5d. PROJECT NUMBER		
				5e. TASK NUMBER		
				5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Queensland St Lucia Brisbane QLD 4072 Australia					8. PERFORMING ORGANIZATION REPORT NUMBER N/A	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AOARD UNIT 45002 APO AP 96338-5002					10. SPONSOR/MONITOR'S ACRONYM(S) AFRL/AFOSR/IOA(AOARD)	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S) 13IOA006_144077	
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution Code A: Approved for public release, distribution is unlimited.						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT This 12-month project conducted detailed studies on the 22 October 1999 great storm, 5 May 2005 superstorm and 21 January 2005 moderate storm. Our main aim was to investigate the various types of perturbation electric fields and their effects on the coupled regions of the low-, mid- and high-latitude ionosphere. Our findings are published already or will be published soon with JGR Space Physics. These studies produced significant scientific results regarding the specification of storm-related electric field events, the description of resultant ionospheric features and the analysis of CTIPe (Coupled Thermosphere-Ionosphere-Plasmasphere Electrodynamics) generated model simulations.						
15. SUBJECT TERMS Ionosphere, Ionospheric Irregularities, Electromagnetic scattering						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Ingrid J. Wysong, Ph.D.	
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include area code) +81-42-511-2000	
U	U	U	SAR	3		

Final report on project entitled: Investigating perturbation electric fields and their effects on the coupled low, mid- and high-latitude ionosphere

Principle Investigator: Dr. Ildiko Horvath (ihorvath@itee.uq.edu.au)

During this 12-month project (AOARD-14-4077; FA2386-14-1-4077), we have conducted detailed studies on the 22 October 1999 great storm, 5 May 2005 superstorm and 21 January 2005 moderate storm. Our main aim was to investigate the various types of perturbation electric fields and their effects on the coupled regions of the low-, mid- and high-latitude ionosphere. Our findings are published already or will be published soon with JGR Space Physics. These studies produced significant scientific results regarding the specification of storm-related electric field events, the description of resultant ionospheric features and the analysis of CTIPe (Coupled Thermosphere-Ionosphere-Plasmasphere Electrodynamics) generated model simulations. The manuscripts submitted received positive reviews.

Demonstrating our contribution to community knowledgebase, one of our previous AOARD funded studies is listed on MIT Haystack Observatory's webpage among the highlighted studies of 2014 (<http://www.haystack.mit.edu/atm/pubs/index.html>). In this report, some significant findings are described and resultant journal articles are listed.

The 22 October 1999 great storm ($D_{st} = -228$ nT) was characterized by the development of four prompt penetration electric (**E**) field (PPEF) events during which the sub-auroral polarization stream (SAPS) **E** field had been strong. During these **E** field events, the repeated development of equatorial ionization anomaly (EIA), storm-enhanced density (SED) bulge and SED plume occurred in those longitude sectors that covered the local dusk-midnight hours. Thus, a well-formed EIA-SED structure exhibited a westward movement as it appeared first in the American sector and later on over the Pacific Ocean and in the Australian sector according to its local time dependence. As the SED plume plasma found its way to the polar region, a tongue of ionization (TOI) formed. In the northern polar cap region, the high plasma densities were nearly seven times of the quiet time values. Meanwhile, a less development was observed in the south. Observational results and CTIPe simulated wind vector maps suggest that 1) the enhanced growth of the EIA transported solar produced plasma to the SED bulge via the net eastward **E** field effects, 2) the mechanical wind effects contributed to the maintenance of the SED bulge's high plasma densities, and 3) the combination of these factors lead to the increasingly better development of polar TOI.

We note here that these results add to our previous AOARD funded work carried out on SED and TOI features. One of our published articles is listed on the MIT Haystack Observatory Atmospheric Sciences Publication webpage (<http://www.haystack.mit.edu/atm/pubs/index.html>). This study produced one journal article that received a very positive review from Prof. J. Sojka (Utah State University).

Horvath, I., and B. C. Lovell (2015), Investigating storm-enhanced density and polar tongue of ionization development during the 22 October 1999 great storm, *J. Geophys. Res. Space Physics*, 120, 1428–1444, doi:10.1002/2014JA020598.

The 15 May 2005 superstorm ($D_{st} = -305$ nT) provided an excellent opportunity to further investigate the ionospheric features of the EIA, SED and polar TOI in different storm phases and to observe hemispherical differences. Two journal articles report our results.

As reported in the first journal article, our observations revealed SED and polar TOI development prior to and during the initial phase over North America during the local evening-pre-midnight hours. Furthermore, a well-developed EIA-SED structure was observed during the main phase and early in the recovery phase in the Asian sector during the local afternoon-evening hours.

Then, the polar TOI was absent in the North because of the long distance from the magnetic North Pole but was present in the south due to the closeness of the magnetic South Pole.

Reported in the second journal article, our investigations revealed also an interesting feature of this storm. This is the development of strong positive and negative phases in the Northern Hemisphere created by the sunward streaming SED plume plasma over Asia and a well-developed mid-latitude trough over North America respectively. Furthermore, our results also revealed the simultaneous development of positive and negative phases over North America as some enhanced auroral ionization appeared in the depleted night-time ionosphere after local midnight. Based on observational and CTIPe simulation results, we concluded for this storm that 1) composition changes contributed to the formation of positive and negative phases, 2) strengthening polar convection and increasing solar heating of the polar cap region supported polar TOI development, and 3) weaker polar convection and minimized solar heating of the polar cap region aided the depletion of polar plasma.

We note here that both manuscripts received very positive reviews and the reviewers commented on the solid studies and high quality results and figures.

Horvath, I., and B. C. Lovell (2015), Storm-enhanced plasma density and polar tongue of ionization development during the 15 May 2005 superstorm, *J. Geophys. Res. Space Physics*, 120, doi:10.1002/2014JA020980.

Horvath, I., and B. C. Lovell (2015), Positive and negative ionospheric storms occurring during the 15 May 2005 geomagnetic superstorm, *J. Geophys. Res. Space Physics* (accepted).

The 21 January 2005 moderate storm ($D_{st} = -101$ nT) allowed us to investigate EIA and SED development taking place in the American sector under varying interplanetary magnetic field (IMF) conditions. We have analyzed various scenarios for conjugate SED development when the EIA present and absent. Our results demonstrate the EIA's significant contribution to SED bulge development and the significance of "snowplow" effects supporting SED development in the EIA's absence. Based on observational evidence we concluded that the underlying plasma-tail reconnection, occurring during northward IMF orientation when daytime reconnection was absent, supported SAPS E field and SED development.

We note here that these results are documented in one manuscript of which preparation is still in progress.

Horvath, I., and B. C. Lovell (2015), Conjugate storm-enhanced density (SED) development in the American longitude sector under prolonged northward B_z conditions: a case study of the 21 January 2005 geomagnetic storm, *J. Geophys. Res. Space Physics* (in preparation).